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RADARSAT PROJECT REPORT 82-9

INFORMATION PRODUCTS REQUIRED FOR ICE AND OCEAN OPERATIONS

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1. INTRODUCTION

1.1 Background

Radarsat Project Report 81-3 entitled "Preliminary Statement of User Requirements for Ice and Ocean Information" dated July, 1981 (Ref. 1) identified seven major user groups that require ice and/or ocean information to support their operations. The groups are:

1. Canadian Coast Guard and General Shipping
2. Oil and Gas Shipping
3. Offshore Drilling and Production
4. Fisheries
5. Meteorology
6. Defence
7. Ice Research and Ocean Research

At present, these groups make use of ice and ocean information products provided by AES Ice Forecasting Central* and the Canadian Forces Meteorological and Oceanography (METOC) Centres.** The products are derived from a variety of data sources including existing satellites, AES Ice Patrol aircraft, buoys, drilling rigs, ships of opportunity and the AES data gathering network. Radarsat will provide an important new source of data for use in ice forecasting and oceanography, the impact of which will depend on the specific suite of sensors to be carried by the satellite. As a minimum, Radarsat will contain a synthetic aperture radar (SAR) capable of providing high resolution (25 m.) imagery under all-weather and darkness conditions.

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* Recently the operations of Ice Forecasting Central have been colocated with the climatology and research divisions in a central facility known as Ice Centre Environment Canada (I.C.E. Canada).

** Established to serve the needs of National Defence, METOC Centres supported by AES staff also provide wave analysis and forecasting services to civilian users.

Orbit and swath-width selection can be adjusted to provide as a minimum, daily coverage of the Beaufort Sea, NW passage and Baffin Bay regions of Canada's Arctic. The frequency of coverage decreases at lower latitudes.

Other sensors that are being considered for Radarsat include a scatterometer capable of providing mesoscale data on wind fields averaged over a 1250 km swath width, a scanning multi-frequency microwave radiometer that provides low-resolution global coverage of ice-water boundaries and ice type concentrations as well as other parameters such as sea-surface temperature, a radar altimeter for geoidal and wave height determinations, and an optical multi-spectral scanner mainly for land-related missions. The exact mix of sensors is not known at present, and will depend on user pressures and the results of economic benefit analyses currently being conducted, (Ref. 2).

Whatever sensor combination is chosen for Radarsat, the raw data will be received in real time by two ground stations at Churchill, Manitoba and Shoe Cove, Newfoundland. SAR and other necessary data processing facilities will be located at these Stations. Raw SAR data received by these stations will be converted to imagery and then transmitted on to users including Ice Forecasting Central in Ottawa for interpretation. Other sensor data received by the ground stations will be processed and then transmitted on to the appropriate user or interpretation centre.

Imagery and other data provided by Radarsat will be blended with data from other sources at Ice Forecasting Central and METOC to produce information products. Such products would be designed and packaged to meet the needs of users such as those set out in the User Requirements document (Ref. 1).

At present, information products are relayed from Ice Forecasting Central and METOC to operational users by a distribution system consisting of radio facsimile broadcast for charts and teletype for narrative and alphanumeric messages. The combination of sensors, sensor platforms, ground receiving stations, data processing facilities, interpretation centres, communication networks and user facilities will be termed the Ice and Ocean Information System.

The Ice and Ocean Information System so constituted is that required to support those ocean operations listed above. In no way does it pretend to be comprehensive in terms of providing all the forms of ocean information required by government agencies and the private sector. For example, the Department of Fisheries and Oceans, through the Canadian Hydrographic Service, provides hydrographic data of vital interest to mariners which is quite outside the Ice and Ocean Information System described herein. Other information sources are used to support fisheries and fisheries management functions. Ocean science groups operate their own information systems.

This document reports on the results of user interaction during which the parameter requirements compiled in Reference 1 have been converted to a set of information products acceptable to users, and capable of being delivered by an Ice and Ocean Information System.

1.2 Radarsat Information Standards Committee

The User Requirements Study revealed that the user groups most likely to benefit from the type of data that Radarsat can add to the existing data sources are as follows:

a) Ice
- Canadian Coast Guard and General Shipping
- Oil and Gas Shipping

b) Oceans
- Offshore Drilling and Production
- Defence
- Canadian Coast Guard and General Shipping

Offshore drilling and production also benefit from better ice information, but the main ice concerns for that user group are those associated with icebergs which cannot always be located reliably by Radarsat. Fisheries benefit to the extent that improved ice and ocean forecasts can be expected from better and more frequent data. Meteorology and Research user groups also will derive benefits from Radarsat documented in the User Requirements Study. However, the major and vital benefits from Radarsat centre on oil and gas shipping which will require ice and oceans information on a year-round basis. The regulatory and enforcement role of the Coast Guard renders it co-dependent with oil and gas shipping on year-round ice information.

In order to define better the types of information products required by these groups and the specific forms such products might take, a Radarsat Information Standards Committee was formed. Information product definitions are required in order to design the Ice and Oceans Information System that must be in place toward the late 1980s when frontier hydrocarbons begin to be transported out of the Arctic by sea. It is perhaps worth noting that such a system may be required even before Radarsat is launched. In fact, it may be necessary to "make do" with data from other satellites and aircraft if year-round arctic and east coast shipping begin before Radarsat is launched. For this reason, it was important that information product planning commence quickly.

The Committee consisted of, but was not limited to the following groups:

- Canadian Coast Guard
- Oil and gas shipping (Arctic Pilot Project and Dome Petroleum)
- Offshore Drilling and Production (Petro-Canada, Mobil)
- CF METOC
- Atmospheric Environment Service (Ice Branch and Meteorological Research Branch)
- Radarsat Project Office
- Spar Aerospace Ltd.
- MacDonald, Dettwiler and Assoc.

The Chairman was Dr. P. A. Lapp, Philip A. Lapp Ltd., the secretary was Mr. D. J. Lapp, Polar Research and Engineering.

The following questions were used to guide the Committee:

a) What are the required forms and formats of information products?
b) How will the operator use the information?
c) How often will the operator require access to information?
d) What time delay is permissible to get information into and out of storage?
e) What are the outputs of the operator's activities?
f) What kind of management information is needed to monitor operations?

Five meetings of the Committee were held as follows:

Meeting No.	Location	Date
1	MacDonald Dettwiler & Assoc. Richmond, British Columbia	September 28 and 29, 1981
2	Canadian Meteorological Centre (CMC), Dorval, Quebec	October 27, 1981
3	Ice Forecasting Central Ottawa, Ontario	November 23, 1981
4	Atmospheric Environment Service, Downsview, Ontario	January 12, 1982
5	Arctic Pilot Project Calgary, Alberta	March 11, 1982

The sites were chosen so that the Committee could combine field visits to a relevant facility with each meeting. This document was prepared from material mainly derived from Committee meetings. A list of meeting attendees appears as Appendix 1.

1.3 Structure of the Report

Operation of the Ice and Ocean Information System is described in Section 2. The system description and evolution is based and built upon present organizational structures without major shifts in form or function. The system is assumed to grow into forms that parallel the present AES meteorological network which thus allows for the sharing of common facilities where and when practicable.

Section 3 examines the range of information products needed to yield the parameters required by users. This exercise results in a selection of those information products that best meet user needs as defined in the User Requirements document, and explored in more depth by the Committee.

Information product requirements vary by activity, location and season. This dependency is investigated in Section 4 which leads to insights on those geographical and temporal factors that impinge on overall system design.

Conclusions and recommendations follow which are intended to assist in the design of the overall system. It is clear that the temporal and geographical needs for ice information are uneven, being heaviest during freeze-up and break-up, and where the ice is moving. Ocean information requirements are more synoptic, but obviously become critical surrounding periods of heavy storms. Recommendations suggest ways in which user input can be coupled to the system design process.

1.4 Limitations

The deliberations of the Radarsat Information Standards Committee have taken place at a time that now is up to eight years before the planned launch of the satellite, and at least five years before vessels including tankers will be operating year-round in the arctic. Undoubtedly, technology and perceived needs will change perhaps considerably before design decisions are necessary. Thus it is important to bear in mind that the findings and conclusions of this report represent early thinking about ice and ocean information needs which will not remain stationary over time.

Also, it should not be forgotten that the first LNG and oil tankers in the Arctic will be operated as prototypes subject to change with operational experience. There likely will be a tendency to overspecify information requirements recognizing that such specifications can be relaxed as experience dictates. The most severe worst-case scenarios probably will form the basis for first-generation design, and it is probable that second-generation information systems will be simpler and more cost effective than the earlier versions.

2. THE ICE AND OCEAN INFORMATION SYSTEM

The Canadian ice and oceans information system is portrayed in Figure 2.1 which shows the essential components in block diagram form. The diagram is divided by the dotted line into two parts -- the existing system below the line, and the future system with Radarsat added above the line. The first row of boxes on the left side of the diagram includes the platforms and associated sensors relevant to ice and ocean information product needs. The raw data outputs are transmitted to receiving stations and/or processing facilities. There the raw data is converted into data products for onward transmission to users and to other locations for further processing. Information products are generated by two Centres - one for ice, the other for oceans. The system also includes those communication facilities needed to transmit data and information from one geographical location to the other. The following paragraphs describe in broad terms the existing system and a future ice and oceans information system containing Radarsat.

2.1 The Existing System

At present ice information products are produced by AES's Ice Forecasting Central located in Ottawa. In an expanded role with a wider range of products to be covered later in this report, the more general name "Ice Information Centre" (IIC) has been adopted by the Radarsat Project and will be used henceforth.

The present IIC receives data products from a variety of sources which include ice charts and SLAR imagery from the AES aircraft (two Lockheed Electras), and visual and infrared imagery from other satellites (Landsat and NOAA) via the Satellite Data Laboratory in Downsview, the Prince Albert, Sonderstrom and the Shoe Cove receiving stations. Ice charts including laser data*

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* From the laser profilometer data, the operator annotates on the ice chart maximum and mean heights and frequency of ridges every 60 miles or so. The raw data is later shipped to Ice Climatalogy for archiving.

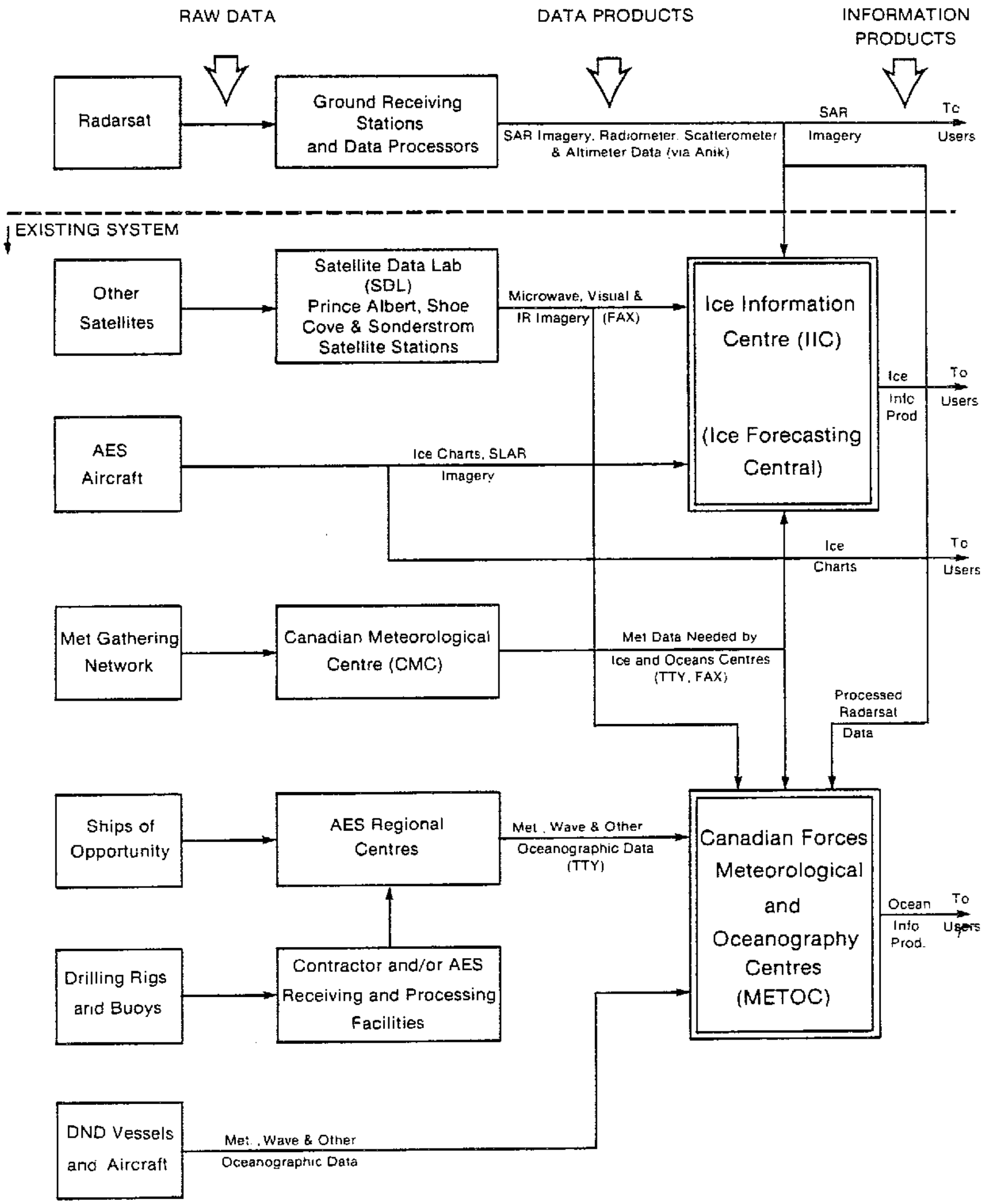

Fig. 2.1 Ice and Oceans Information System

from the aircraft are transmitted in real time by HF circuits to IIC. Ships in the vicinity of the aircraft also can receive the charts directly. SLAR data is sent by Airvelope after the aircraft lands. The IIC combines the disparate data products it receives into a Daily Ice Analysis Chart which is a composite of ice conditions in an area usually at a scale of 1:2,000,000. Meteorological data is required in modelling for the production of ice forecasts which are being planned for the near future. Thus data products from the Canadian Meteorological Centre (CMC) are included in Figure 2.1. Regional and local meteorological data also will be required to support prognostic ice charting.

The Daily Ice Analysis Chart is transmitted to Halifax, Frobisher and Resolute where it is put out on HF facsimile broadcasts. It goes out in the late afternoon, but recently the chart has been supplemented by a text-only update the following morning.

Research is now underway to demonstrate the ability of the passive microwave radiometer on NIMBUS 7 to provide mesoscale information on ice type and concentration as well as ice edges. As part of the program, attempts are being made to establish a direct data link between Ice Central and Fleet Numercial Oceanographic Center (FNOC) for NIMBUS 7 to use as an additional information source in the preparation of ice charts. This operational demonstration also will use algorithms and compatible formats to permit gridded values of ice type and concentration to be used as input into the present ice models. Success in the program would establish the value of passive microwave data in AES Ice Branch reconnaissance and forecast activities.

Ocean information products are provided to users through the Canadian Forces Meteorological and Oceanography (METOC) Centres - one in Halifax, Nova Scotia, the other in Esquimalt, British Columbia. The principle products are twice-daily wave data charts and forecasts (12, 24 and 36 hr.), and the semi-weekly sea surface temperature (SST) and oceans features charts. The latter provides 3-dimensional information on water classifications based on temperature and salinity for use mainly in underwater acoustics. These products are sent out by Canadian Forces HF facsimile broadcast facilities on both coasts.

The data products needed to generate this information are received by METOC Centres from a variety of sources:

- CMC for basic met. prognoses
- SDL for IR and other satellite imagery
- AES Regional Centres for local met., wave and other oceanographic data received mainly from ships, oil rigs and buoys.
- DND vessels and aircraft for met., wave and other oceanographic data.

2.2 The System with Radarsat Added

Radarsat adds considerable data collection capacity to the existing system. Ground receiving stations will convert raw data received from the satellite into imagery and other data products determined by the sensors carried on board. During a satellite pass, raw SAR data is recorded on high-density digital tape. When the pass is completed, the tape is rewound and played back into the SAR Data Processing System. The processor then produces raw SAR radar imagery at one quarter the rate it is acquired by the satellite. The imagery so produced is in slant range/azimuth coordinates, and the image data stream exiting the SAR processor will have geo-referencing* information imbedded as well as other information which indicates time, orbit number, swath identification, etc. From this data, four SAR image products will be produced:

1. Low-Resolution Georeferenced Swaths
2. Low-Resolution Georeferenced Scenes
3. High Resolution Georeferenced Scenes
4. Geocoded Subscenes

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* Georeferenced satellite imagery is produced by removing systematic sensor and orbit errors. Images so corrected are rectangular with the vertical direction representing the heading angle of the spacecraft (azimuthal direction) and the horizontal representing the range direction.

The ground station will generate a low-resolution georeferenced swath immediately after every satellite pass in ground range/ azimuth coordinates (a projection onto the plane of the earth's surface), and with a reduced pixel (picture element) resolution of 100 m. While the imagery will be available to users in "bulk swath" form, the ground station will convert the swath into separate 175 km. x 175 km. scenes - a format suitable for transmission over a low-speed communications channel. The scenes from a 15-minute satellite pass, for example, will be available in the order of 20 minutes after the start of the pass, and about one hour will be needed to receive all such scenes from the pass.

While low-resolution georeferenced scenes will have the highest priority at the ground station, high resolution (25 m.) georeferenced scenes also will be produced from slant range/azimuth imagery by removing systematic sensor, platform attitude and orbit errors. These images will be transmitted to end users over high- or low-speed digital links as desired, or stored on computer-compatible tapes (CCTs) or film for dissemination to users.

Geocoded satellite images use a specified map projection (e.g. UTM) for the final output coordinate system where the image is rotated to a north/south alignment. Geocoding will be carried out on subsets of radar scenes resulting in a subscene consisting of an integral number of National Topographic System (NTS) map sheets. Geocoded subscenes shall be produced on both full (25 m x 25 m) and reduced (50 m x 50 m) resolution to satisfy requirements of land and ice/ocean users respectively.

The above description of Radarsat SAR imagery was drawn from MDA report "Radarsat Ground Stations Performance Requirements and Design Concepts", dated March, 1982 (Ref. 5). The design of the Radarsat system is on on-going, evolutionary process and so the SAR image products and their characteristics could change significantly throughout the course of the Radarsat design and development program.

Radarsat likely will carry other sensors in addition to SAR. For ice and oceans applications, they may be one or more of the following:

- scanning multi-frequency microwave radio-meter (SMMR)
- altimeter
- scatterometer
- visual/infrared multi-spectral scanner (VIR sensor)

The SMMR can provide small-scale, global coverage of brightness temperature every three days for a variety of frequencies at at vertical and horizontal polorizations. These data would be converted to geophysical parameters such as sea surface temperature and ice concentration.

Altimeter data could be of value to METOC users. Data processors at the ground receiving stations would supply altimeter data products to the centre. METOC might use the data to measure wave heights directly, and to establish geoidal features. The latter also may be of interest to the Canadian Climate Centre (CCC) because of the geoidal effects on world ocean circulation.

Scatterometer data will be used principally by METOC to deduce wind fields from which wave information products can be computed. As with the other sensors, scatterometer data products will be generated at the ground receiving stations and transmitted to METOC via an Anik channel.

2.3 Communications

Communications aspects of the ice and oceans information system can be structured in the same fashion as the AES communications system now in place, and which recently has been subjected to a major study (Ref. 3). Following the same pattern, the system can be considered to contain three different nodes called processors:

- main processors (MPs)
- intermediate processors (IPs)
- user processors (UPs)

The principal main processors are the IIC and METOC centres which generate information products using data received from other MPs that already are nodes in the meteorological portion of the AES communications system. They include SDL, CMC and the AES Regional Centres (although the latter are considered to be IPs in the main AES system). The Radarsat data processor(s) also will be MPs. The MPs transmit information that is mainly synoptic and national in character. The synoptic interval for the ice system is likely to be twice daily, the same as the oceans system (wave program), but it is not yet necessary to settle on this figure.

Intermediate processors are interposed between MPs and some users. They will receive and store regional and asynoptic information. Some user groups that might choose to establish

IPs include the oil and gas shipping industry or individual companies in Calgary or Tuktoyaktuk, the fisheries interests on either coast or an oil company operating several drilling rigs.

User processors will be located at a user site such as a tanker vessel or Coast Guard ship, drilling etc. UPs also include archival facilities such as the Canadian Climate Centre (CCC) or the Marine Environmental Data Service (MEDS) that store regular products from the MPs, or special products generated specifically for archival purposes.

The communication system will, of necessity, require distributed storage. The distribution of storage facilities will determine bandwidth requirements of the communication links for a given set of user requirements. In general, storage location should be selected to minimize spectrum utilization on the basis that spectrum costs will rise in future, whereas storage costs will likely continue to fall.

A wide variety of communications media are used in the present system ranging from Anik to Airvelope. The critical links will be those to the UPs on board ships with limited antennas and receiver facilities, and yet which may need wide bandwidths to accommodate the time and quality requirements of imagery reception. M-Sat may not provide adequate bandwidth, and available Aniks may not have a suitable footprint over the entire route of the vessel.

In order to permit zoom and roam operations on board ship, imagery would have to be transmitted to and stored on board vessels in digital form. The transmission bandwidth will determine the speed at which such imagery can be sent to and accumulated on board. Otherwise, images could be sent and stored in a video mode with far less stringent bandwidth requirements. The final selection will depend on detailed design tradeoffs that need to be conducted by each user balancing cost against overall effectiveness of the various system options in reducing risk to the vessel from ice damage and inefficient route selection.

It is not the purpose of this report to examine such communications options, but rather to suggest where further information and decisions are needed. The following sections examine in some depth the nature of the information that will be communicated throughout the system, who needs it, and how it will be used. Such an examination should narrow the range of options open to the system designer and thus contribute to an early resolution of design decisions.

3. GEOPHYSICAL PARAMETERS AND INFORMATION PRODUCTS

The User Requirements Study (Ref. 1) identified lists of ice and ocean geophysical parameters under the headings of planning, strategic and tactical requirements. From these lists, a combined list has been drawn up covering all the parameters identified as needed by users. Where parameters appeared under more than one of the headings, the difference usually was in the stringency of the specifications - tactical requirements being more stringent than the others.

Since ice and ocean information products already are being produced operationally, the approach was to build on what now exists. The following paragraphs describe future information products proposed by the current operators in an expanded role with Radarsat added, and the degree to which these products can provide the geophysical parameters required by users.

3.1 Ice Information Products

IIC has proposed an evolution of information products which reflect improvements in the ability to forecast using more sophisticated models and better input data products to initialize the models, and the advent of Radarsat with its daily SAR coverage of the critical areas of the Arctic and possibly other sensors.

3.1.1 Present Products

The present products provided to users are derived principally from the AES aircraft in the form of hand-drawn charts and SLAR imagery, and from satellites that provide visual and infra-red imagery. The information products are:

a) <u>Ice Charts</u> - which can be received directly from the AES aircraft by ships in the vicinity, as they are being transmitted to the Ice Information Centre in Ottawa.

b) <u>Daily Ice Analysis Charts</u> - provide a synthesis of all available data depicting daily ice conditions in areas such as Baffin Bay, Beaufort Sea, Parry Channel, etc., normally at a scale of 1:2M. They provide information on the principal ice parameters including ice concentration, ice type, ice thickness, floe size and ice motion.

c) <u>Narrative Forecasts</u> - provide an outlook for ice conditions in a message form detailing expected ice distribution and movement as well as information on iceberg locations when available. These outlooks can be received by telecopier or by marine radio.

3.1.2 <u>Future Products</u>

A 1990 scenario was drawn up where it was assumed that daily SAR imagery would be available from Radarsat, and that ice dynamic models had been developed capable of providing 12, 24, 48 and 72 hour prognoses with adequate initializing data. The proposed future information products are as follows:

a) <u>Direct Ice Imagery</u> - as described in Section 2.2, Radarsat SAR imagery will be available directly via Anik to those users with suitable receiving facilities. Also aircraft SLAR or SAR could be downlinked for tactical support.

b) <u>Relayed Ice Imagery</u> - on receipt of SAR imagery, IIC will format it and relay it back to users as described in Section 2.2.

c) Daily Ice Analysis Charts - will continue to be the principal product from IIC which may be needed twice daily where the ice is highly dynamic. The parameters will include ice distribution, type and inferred thickness, floe sizes, topography, motion and pressure. It also provides the initial data for the ice models.

d) Ice Interpretive Charts - analysis of SAR and other satellite imagery by IIC providing parameters similar to the ice analysis charts but in more detail which also may suffice for tactical support in some regions of the Arctic.

e) Ice Ridge Distribution Charts - a combination of SAR/SLAR imagery, laser data and ships reports should generate sufficient information on ridges to produce a weekly ice ridge distribution chart in the areas of operational interest.

f) Prognostic Ice Charts - it is proposed that prognostic ice charts* be available twice daily covering T + 12, T + 24, T + 48 and T + 72 hours. Two sets of charts are envisaged - one covering ice concentration and thickness, the other providing ice drift and pressure.

g) Iceberg Distribution Charts - the present proposal is to provide on a daily basis a chart showing the overall iceberg distribution, identifying iceberg population in areas of half of a degree of latitude and longitude. Regions might include Labrador Coast, east Newfoundland waters, Davis Strait and Baffin Bay. A prognostic iceberg distribution chart also may be available in future.

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* Present ice modelling work is expected to generate charts of this type within a year.

h) Vessel Location Map - this product was not proposed by IIC, nor does it fall within the AES responsibility mandate. It arose from a perceived need for some form of vessel traffic management (VTM) which would fall under the purview of the Coast Guard. Should VTM be required in the NW passage, then CCG may conclude there is a need for a vessel location map. Also it is needed for search and rescue operations.

i) Narrative Forecasts - They include daily outlooks (short range 24-48 hours plus a separate 3-5 day outlook) and chart amendments or updates. Also, IIC could provide tailored ice analyses or forecasts, and extended special forecasts (15, 30 day and seasonal outlooks) including expected times of freeze-up and break-up.

In general it might be stated parenthetically that most parameters could be specified using alphanumeric as opposed to chart products, which would reduce the cost of communications. However, future operators have indicated their preference for imagery (at least at present) over charts for the purpose of ship routing. Others (CCG and AES) question the need for transmitting imagery to users if the ice analysis and other charts can be improved adequately.

3.1.3 Required Ice Geophysical Parameters

The parameters laid out in Table 3.1 are the critical ice parameters listed in the User Requirements Study (Ref. 1). The table attempts to delineate which products are capable of providing strategic or strategic and tactical requirements in accordance with the specifications of Reference 1 (Tables 3.1 and 3.3). The two main distinctions between them is, level of

Ice Information Product / Ice Geophysical Parameter	Direct Ice Imagery	Relayed Ice Imagery	Daily Ice Analysis Charts	Ice Interpretive Charts	Ice Ridge Distribution Charts	Prognostic Ice Charts a) Concentration/ Thickness b) Drift/Pressure
TYPE/BOUNDARY	S,T	S,T	S,T	S,T	–	–
CONCENTRATION	S	S	S	S,T	–	S,T
THICKNESS	–	–	S	S	–	S,T
EDGE	S,T	S,T	S,T	S,T	–	–
LANDFAST ICE	S,T	S,T	S,T	S,T	–	–
LEADS	S	S,T	S,T	S,T	–	–
FLOES	S,T	S,T	S,T	S,T	–	–
ISLANDS	S	S	S	S	–	–
RIDGES	–	S	S	S	S,T	–
PRESSURE	S,T	S,T	S,T	S,T	–	S,T
MOTION	S,T	S,T	S,T	S,T	–	S,T
DETERIORATION	S?	S	S	S	–	–
SNOW COVER	–	–	S	S	–	–

S - STRATEGIC

T - TACTICAL

TABLE 3.1 ICE GEOPHYSICAL PARAMETERS VS INFORMATION PRODUCTS detail (spatial resolution) and turnaround time. The limitation of 25 meter resolution for the satellite imagery eliminates this product for some tactical applications. However, the major limitation is turnaround time which, for some of the parameters, is indicated as "instantaneous" in Ref. 1, Table 3.3. Upon more detailed examination, the instantaneous turnaround requirement was applied to certain critical aspects of offshore drilling/production, and what one oil and gas shipping user terms "close tactical surveillance" which could only be met by on-board sensors or helicopters. A turnaround time of 2 hours will meet most user tactical requirements. Also, while certain users stated formally that coverage repetition as frequently as every 3 hours is needed for some tactical parameters, closer examination revealed that this requirement could be relaxed to once daily when vessel-based close tactical support is deployed. We conclude that satellite imagery that can be turned around in 2 hours or less, that provides daily coverage, and achieves 25 meter resolution can meet most tactical as well as strategic requirements.

Table 3.1 covers five of the eight information products proposed for ice. Applications for two of the remaining three - ice-berg distribution charts and vessel location maps are self evident. The final product, narrative forecasts, was proposed by IIC as a special long-range outlook service, and to provide for specifically-tailored user requests. It is expected that the present narrative forecasts would continue to be provided to users which do not have the capability to receive more sophisticated data products.

3.2 Ocean Information Products

The CF METOC centres produce a range of ocean information products needed by DND, some of which also satisfy operational needs of the civilian user community. The present system, shown in Figure 2.1, relies heavily on ships of opportunity including DND vessels and aircraft for its sources of data. Such sources are, at best, intermittent, and the quality of data from individual ships is uneven. Radarsat could add an important data stream to METOC because of its regularity and consistency, if an appropriate second sensor is added. One sensor candidate is a scatterometer which would provide wind magnitude and direction data over a 1250 km swath at coverage intervals of 12 hours or less at Canadian latitudes.

The Seasat experience with an altimeter showed this instrument might be used to measure significant wave height in addition to its use in measuring geoidal features. However, its narrow swath (a few kms.) could be a limiting feature. The third sensor of interest is a scanning multi-frequency microwave radiometer (SMMR) which could include channels for measuring sea surface temperatures. This type of data currently is being collected by the US using a SMMR on Nimbus 7 which has a limited orbit lifetime.

METOC currently puts out the following ocean information products:

a) Wave Data Charts - twice daily at a scale of 1:15M, derived mainly from ship data but uses wave forecasting techniques (such as Brettschneider's nomogram) from wind data where no wave data is available. Significant wave forecasting techniques are used to generate T+12, T+24 and T+36 hour prognosis charts.

b) Sea Surface Temperature Charts - twice weekly at a scale of 1:10M, derived principally from ship and buoy data, and from satellite IR.

c) Ocean Features <u>Analysis Charts</u> - twice weekly at a scale of 1:10M showing 3-dimensional information on warm and cold eddies, and water classifications based on temperature and salinity for use in underwater acoustics. Data is derived from vessels and IR imagery.

The above products are essentially those required by the Canadian Forces, and do not reflect all the operational needs of the civilian ocean community. However, the wave products have a wide range of applications according to a recent evaluation of the METOC wave program by civilian users (Ref. 4). Since the Radarsat scatterometer will improve immensely the quality of an existing product, its value can be assessed readily because the user community has already been identified.

The User Requirements study listed requirements for the following ocean parameters:

- Seastate - height, period, direction and spectra
- Swell - height and period
- Wind - velocity and direction
- Sea Surface Temperature
- Surface Currents
- Ocean Colour
- Salinity
- Chlorophyll

It is evident that METOC products do not provide for all of these. Moreover, there are no plans for government facilities to provide for them in the foreseeable future. Thus users requiring such parameters have to establish their own facilities, which indeed is occurring in the case of offshore drilling and production. Such operators use environmental consultants that operate their own data collection systems including buoys in the vicinity of the rigs. Meteorological and oceanographic models have been developed by the consultants, and while their data feeds into the AES network, they provide their own site-specific forecasts to meet client requirements. Consultants contacted by the study team indicated great interest in the scatterometer data stream that would flow from Radarsat, because of the improved wind field knowledge it provides. Ocean routing is another service being provided by environmental consultants that requires better wind field data.

Biological parameters such as ocean colour and chlorophyll seem still to be in the domain of the researcher. Surface currents generally measured from moored buoys and fixed structures are not readily measured remotely. The remaining parameter, salinity, is not readily measured remotely from a satellite, and while it is important to biologists and for underwater acoustics, there is no regular salinity data gathering program outside the military and research communities.

A parameter that did not arise during the initial iteration of the User Requirements study but desired by some operators is ice accretion. The corresponding product would be a chart that provides current and forecast ice build up (in mms/hr) which depends principally on wind, temperature and salinity. This product is of particular interest to search and rescue operations, shipping, drill rig operators and fishing fleets that operate off the east coast. AES Regional Centres currently produce site specific information, but chart products are preferred by some users. According to AES, ice accretion charts will be introduced during 1983. Also AES is required to provide information on the location and expected trajectories of oil spills in the event of an emergency.

In summary, Radarsat data would be used to improve existing ocean information products - the scatterometer and possibly the altimeter for wave products, the SMMR possibly for sea surface temperature, windspeed and oceans features analysis products.

4. INFORMATION PRODUCT REQUIREMENTS BY ACTIVITY

4.1 Introduction

The information products currently in use and those proposed to the Information Standards Committee and described in Section 3 were agreed upon by the users present and involved in the meetings of the Committee. Each user has need for the information in a different way. The needs also differ depending on activity, time of year and geographical location. In order to gain an overview of total ice and ocean information requirements, an attempt was made to canvas key members of the user community concerning their needs for a specific set of information products. The products agreed upon were as follows:

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

Some of the information products described in Section 3 have been combined in the above list. The list was used to elicit the temporal and geographical needs for these products in order of priority from the principal users. Examples of some of the above information products are contained in Appendix 2.

In general, the needs for ice information has been summarized by IIC as follows: Where and when pack ice is present and mobile, an overview of ice conditions is required in the area as observed in the Imagery and depicted in the Ice Analysis Chart (Products 1 and 2). Also, forecasts of changes will be required for an appropriate time into the future (perhaps 1-3 days as in Products 4 and 5). In areas where close to very close pack first year ice and/or multi-year ice must be traversed, information on ridges is required (Product 3). Where icebergs can be encountered, information on their distribution is needed (Product 6). For a transit, this information will define a preferred route, potential areas of difficulty or hazard, and where there is need for tactical and close tactical support.

Because of the daily coverage, turnaround time and resolution of Radarsat SAR imagery, Ice Imagery and Interpretive Charts (Product 1) are capable of providing tactical support for most situations prevailing across the NW passage. Where icebergs, bergy bits and growlers are encountered, particularly in open water, close tactical support always will be required where the sensors are based at the user site. Aircraft visual and remotely sensed observations also will be needed to generate the Iceberg Location Map.

In areas of consolidated ice cover, for example, western Parry Channel from December to July, the need for updated ice information becomes minimal except for thickness data. In contrast, after break-up the conditions may be less severe but, because the ice is in motion, the need for updates increases.

The requirements for oceans information are somewhat less seasonal than ice, but for the major user - offshore drilling and production - no less critical. The cost of a lost day of drilling is in the order of $600,000 per rig and yet many of the operations performed on a drill-rig are sensitive to wind and waves. Thus environmental forecasting is critically important to the planning of rig operations and the Wave Data Charts (Product 8) provide valuable year-round information to the forecaster.

Products 9 and 10 relate principally to ocean acoustics and are thus of value to military anti-submarine warfare operations. However, Product 9, sea surface temperature, is also of interest to meteorologists and the fisheries. Product 7, the Vessel Location Map is needed for Search and Rescue operations and possibly Vessel Traffic Management (VTM) purposes in the future. The Ice Accretion Chart (Product 11) is needed wherever severe spindrift conditions occur, affecting drill rigs and vessels in the presence of freezing spray.

The above qualitative statements serve to introduce the Activity/Information Product matrix exercise conducted by the Information Standards Committee. The results are portrayed in Tables 4.1 to 4.4. The following paragraphs deal with each of the four major user groups' geographical and seasonal needs.

4.2 Oil and Gas Shipping

Table 4.1 was derived from input received from the Arctic Pilot Project and Mobil Oil Canada Ltd. The requirements for the first two locations which cover movements from the Beaufort Sea through Amundsen Gulf and Prince of Wales Strait were proposed by the writers in the absence of definitive information from the Beaufort Sea operators. APP provided details from Western Parry Channel to the Gulf of St. Lawrence, and Mobil for the Grand Banks and Scotian Shelf.

The time needs for nowcast and forecast and frequency of coverage is compatible with Radarsat SAR imagery production, the highest priority product listed. Ice forecast products also command a high priority. As might be expected, wave and iceberg products are important in open ocean situations. Mobil proposed the addition of an Ice Accretion Chart (Product 11) and listed it for the Grand Banks and Scotian Shelf locations. Had the others also considered this product, it may have appeared all the way up to Lancaster Sound. Undoubtedly ice accretion is a major factor in the Labrador Sea most of the year but particularly in winter because of the unusually heavy seas and severe cold encountered in that region.

4.3 Canadian Coast Guard

The information contained in Table 4.2 was provided by the Canadian Coast Guard (CCG), Fleet Systems. The needs of Coast Guard for ice information are not limited to Escort and Transit, but cover administration and enforcement roles, and response to emergencies such as search and rescue or oilspills.

Fleet Systems point out that Product 5 - Forecast Ice Drift/ Pressure - is not a requirement during periods when ice is consolidated, i.e. December - July in several areas, but is a requirement from break-up to the following freeze-up, i.e. July - November. Alternatively, Product 3 - Ice Ridge Distribution - is mainly needed after freeze-up until break-up the following summer. Product 6 - Iceberg Location Map - is required only in some waters which has been indicated by a footnote. For example, in the third location, icebergs could be present in Lancaster Sound, Navy Board Inlet, Baffin Bay and Davis Strait, but would not be in some of the other straits and channels mentioned.

Coast Guard points out that activities are limited in some parts and likely will remain so. For example, operations into Jones Sound, Norwegian Bay and Eureka Sound are limited to one or two trips to Eureka and/or Tanquary Fiord each year in late August/early September and a change is not foreseen. Also, while there could be activities in eastern Hudson Strait/Ungava Bay in winter months in the next decade, CCG do not foresee any activities in Hudson Bay/Foxe Basin in the January-June period. Fury and Hecla Strait is being investigated as an alternate route for future LNG and oil tanker traffic and, if this were to materialize, Foxe Basin and the Gulf of Boothia would become prime areas of concern. The same situation exists regarding routes north of Lancaster Sound to Cameron and King Christian Islands. If oil and gas (discovered in sufficient quantitites) are not collected by pipelines to a more southerly shipping point, then tanker traffic could occur north of Lancaster Sound.

It is noteworthy that Table 4.2 shows Ice Imagery (Product 1) at a priority lower than the Ice Analysis Chart (Product 2) and the forecast products, (Products 4 and 5). The rationale is to minimize the transmission of imagery. There is still considerable doubt as to whether CCG would be prepared to make the capital investment for imagery reception on its icebreakers with the possible exception of the very large vessels. Moreover, CCG argue the addition of Radarsat should improve the quality of charts and narrative forecasts, which may obviate the need for imagery in the hands of the captain.

4.4 Offshore Drilling and Production

Shown under three activities in Table 4.3 - exploration, construction and production - offshore drilling and production is limited to fewer locations than the other user groups. Information needs at the Grand Banks and Scotian Shelf locations were provided by Mobil Canada Ltd. The balance of the table was proposed by the writer. Attention is drawn to the footnotes that accompany the table. The time needs and frequency specifications were suggested by Mobil.

The needs of this user group focus strongly on forecast products and, of course, iceberg distribution where encountered. Wave Data Charts (Product 8) also are of obvious significance. However, it should be noted that offshore rig operators have their own environmental consultants that generate their own products, but who naturally would make use of IIC and METOC data and information products as needed.

4.5 Defence

The METOC ocean information products have been designed specifically to meet DND needs. However, as Table 4.4 (prepared by DND) indicates, DND has a requirement for ice information as well. While CF vessels do not conduct operational exercises in waters containing sea ice and icebergs, ship movements are routinely conducted in such waters. Maritime Command conducts ship deployments in these waters to support fisheries surveillance.

In addition, DND and Coast Guard jointly man the Rescue Coordination Centres (RCCs) which coordinate all Search and Rescue operations. There is a requirement that the Canadian Forces

Weather Offices located at these facilities have ice information readily available. The Canadian Forces also respond to environmental disasters such as oil spills. In order to respond adequately to disasters in ice-frequented waters, detailed ice information must be immediately available.

4.6 Fisheries

While an Activity/Information Product matrix was not prepared for fisheries, the User Requirements study listed the parameters required by the fishery operators and researchers (Table 2.5, Ref. 1), derived from interviews and a special questionnaire. It is evident from the parameters listed that the products of interest are:

2. Ice Analysis Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg, Location Maps - Nowcast and Forecast
8. Wave Data Charts - Nowcast and Forecast
9. Sea Surface Temperature Chart

Also stated was a need for wind speed and direction. The main regions of interest extend through Canadian waters up to the tip of Labrador.

While most individual fishing vessels are unlikely to carry sophisticated receiving and chart recording equipment on board, it is possible that certain shore-based facilities could be capable of receiving some or all such products for use in directing the major fishing fleets. However, it should be emphasized that this approach has not been suggested by or to the major Canadian fisheries companies. Unfortunately, the present state of the economy in respect to the fishing industry is not conducive to significant investment decisions of this nature. However, as operations move towards larger vessels capable of coping with more severe ice conditions, fisheries operators will need to gain wider access to the ice products.

4.7 Other User Groups

The remaining user groups fall under the headings of meteorology and research. Both of these groups have expressed varying degrees of interest in Radarsat data products for their own purposes as outlined in the User Requirements study. However, the IIC and METOC information products have been designed for operational use, and except when a field trial or measurement program is in progress, the interest of these groups in using such products appears to be minimal. Both groups are relied upon to improve the quality of forecast products. Thus there always will be a close interaction between IIC, METOC, the meteorology and the research community.

TABLE 4.1 ACTIVITY/INFORMATION PRODUCT MATRIX (Page 1 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENCY
Oil and Gas Shipping	Beaufort Sea	Jan-Apr	1, 4, 5, 3, 2	2 - 6 hrs.	12 - 48 hrs.	Daily
Movement		May-July	1, 5, 4, 2			
		Aug-Sept	1, 5, 4, 2, 8			
		Oct-Dec	1, 4, 5, 2, 3			
	Amundsen Gulf Prince of Wales Strait	Jan-Apr	1, 4, 3			
		May-July	1, 4, 2, 5			
		Aug-Sept	1, 4, 2			
		Oct-Dec	1, 4, 2, 3			
	Western Parry Channel (Viscount Melville Sound and Barrow Strait)	July-Sept.	1, 2, 4, 5			
		Oct-Nov.	1, 2, 4, 5			
		Dec-June	1, 2, 3, 4, 5			
	Eastern Parry Channel	July-Aug	1, 2, 5, 8, 6			
		Sept	1, 8, 6			
		Oct-Nov	1, 2, 4, 5, 8, 6			
		Dec-Apr	1, 2, 4, 5, 6			
		May-June	1, 2, 5, 6			
	Baffin Bay	July-August	1, 2, 5, 8, 6			
		Sept-Oct	1, 2, 8, 6			
		Nov-Dec	1, 2, 4, 5, 8, 6, 11			
		Jan-Apr	1, 2, 3, 4, 5, 6			
		May-June	1, 2, 3, 4, 5, 6			

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

TABLE 4.1 (Cont'd) ACTIVITY/INFORMATION PRODUCT MATRIX (Page 2 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS		FREQUENCY
				NOWCAST	FORECAST	
Oil and Gas Shipping	Davis Strait	May-July Aug-Oct Nov-Dec Jan-Apr	1, 2, 4, 5, 6 1, 2, 8, 6 1, 2, 4, 5, 8, 6, 11 1, 2, 4, 5, 6, 11	2 - 6 hrs.	12 - 48 hrs.	Daily
Movement	Labrador Sea	May-Dec Jan-Apr	8, 6 1, 2, 4, 5, 8, 6, 11			
	Gulf of St. Lawrence including Strait of Belle Isle	May-Dec Jan-Apr	8, 6 1, 2, 3, 4, 5, 6, 11			
	East Coast of Newfoundland, Grand Banks	May-Dec. Jan-Apr	8, 6, 9, 10, 11 2, 3, 4, 5, 6, 9, 8, 11			
	Scotian Shelf	May-Dec Jan-Apr	9, 8, 10 9, 8, 10, 11			

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
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5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

TABLE 4.2 ACTIVITY/INFORMATION PRODUCT MATRIX (Page 1 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS (1)		FREQUENCY (1)
				NOWCAST	FORECAST	
Canadian Coast Guard Escort, Transit and others such as VTM, administration of ASPRR and response to emergencies	Beaufort Sea Amundsen Gulf	Dec-July	2, 4, 1, 3, 5 (2)	3 - 6 hrs		
	Prince of Wales Strait	Aug-Sept	2, 4, 5, 1	6 - 12 hrs	12 - 72 hrs	Daily
	Western Parry Channel (VMS & Barrow Strait)	Oct-Nov	2, 4, 5, 1, 3			
	Dolphin and Union Strait Coronation Gulf Dease Strait	Dec-June	2, 4, 1, 3	3 - 6 hrs.		
	Queen Maud Gulf Victoria Strait	June-Sept	2, 4, 5, 1	6 - 12 hrs.	12 - 72 hrs.	Daily
	Simpson Strait Rae Strait	Oct-Nov	2, 4, 5, 1, 3			
	James Ross Strait Franklin Strait McClintock Chn.					
	Byam Martin Chn. Austin Channel Wellington Chn. McDougall Sound Crosier Strait	Dec-July	2, 4, 1, 3, 6	3 - 6 hrs		
	(Con't next page)					

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

TABLE 4.2 (Cont'd) ACTIVITY/INFORMATION PRODUCT MATRIX (Page 2 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS (1) NOWCAST	TIME NEEDS (1) FORECAST	FREQUENCY (1)
Canadian Coast Guard (Cont'd)	(cont'd) Queens Channel Penny Strait Belcher Channel Lancaster Sound Peel Sound Prince Regent Inlet Navy Board Inlet Eclipse Sound Baffin Bay Davis Strait	(cont'd) Aug-Sept Oct-Nov	2, 4, 5, 1, 6 (2) 2, 4, 5, 1, 3, 6 (2)	6 - 12 hrs. (4)	12 - 72 hrs.	Daily
	Jones Sound Norwegian Bay Eureka Sound Greely Fiord	Aug-Sept	2, 4, 5, 1, 3, 6 (2)	3 - 6 hrs. (3) 6 - 12 hrs. (4)	12 - 72 hrs.	Daily
	Hudson Strait Hudson Bay Foxe Basin	Jan-May June-July Aug-Oct Nov-Dec	2, 4, 5, 1, 3, 6(2) 2, 4, 5, 1, 6(2) 2, 4, 5, 1, 6 (2) 2, 4, 5, 1, 3, 6(2)	3 - 6 hrs. (3) 6 - 12 hrs. (4)	12 - 72 hrs.	Daily
	Labrador Sea East Coast Nfld. Belle Isle Strait	Dec-June July-Nov Aug-Nov	2, 4, 5, 1, 6 2, 4, 6 6	3 - 6 hrs. (3) 6 - 12 hrs. (4)	12 - 72 hrs.	Daily
	Gulf of St. Lawrence	Dec-May	2, 4, 5, 1	(3) 3 - 6 hrs. 6 - 12 hrs. (4)	12 - 72 hrs.	Daily

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

Footnotes to Table 4.2

1. Time needs and frequency stated could vary with conditions and seasons, i.e. the need for short turn-around and frequent updates would be greater when ice is subject to movement and pressure than when ice is consolidated and nothing changes except thickness.

2. Where applicable

3. Nowcast or turnaround requirement for imagery (Product 1) only.

4. Required turnaround for all other specified products except 1.

TABLE 4.3 ACTIVITY/INFORMATION PRODUCT MATRIX (Page 1 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS		FREQUENCY
				NOWCAST	FORECAST	
Offshore Drilling & Production	Beaufort Sea (2)	July Aug-Sept Oct	1, 5, 4, 2 1, 4, 5, 2, 8 1, 4, 2, 5	2 - 6 hrs.	12 - 48 hrs.	Daily
Exploration (1)	Beaufort Sea (3)	Jan-Apr May-July Aug-Sept. Oct-Dec	1, 4, 2, 5, 3 1, 5, 4, 2 1, 2, 8 1, 2, 5, 4			
	Beaufort Sea (4)	Jan-Apr May-July Aug-Sept Oct-Dec	1, 2, 3, 4 1, 2 1, 2, 8 1, 2, 4, 3			
	Baffin Bay/Davis Strait (5)	June-July Aug-Oct	1, 6, 5, 2 1, 6, 8, 2			
	Labrador Sea (6)	Jan-Apr May-Dec	1, 6, 2, 4, 5, 9 8, 1, 6, 5, 2, 9			
	Grand Banks	Jan-Apr May-Dec	1, 2, 3, 4, 5, 6, 9, 8, 11 8, 6, 9, 10			
	Scotian Shelf	Jan-Apr May-Dec	9, 8, 10, 11 9, 8, 10			
Construction	Beaufort Sea (8)	July Aug-Sept Oct-Dec	1, 5, 4, 2 1, 5, 8, 2 1, 5, 4, 2			

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

TABLE 4.3 ACTIVITY/INFORMATION PRODUCT MATRIX (Page 2 of 2)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS		FREQUENCY
				NOWCAST	FORECAST	
Offshore Drilling & Production (Cont'd)	Labrador Sea	June-Nov	8, 6, 1, 2, 5	2 - 6 hrs.	12 - 48 hrs.	Daily
Construction (7)	Grand Banks	Jan-Apr May-Dec	1, 2, 3, 4, 5, 8, 11 8, 6			
	Scotian Shelf	Jan-Apr May-Dec	8, 11 8			
Production	Beaufort Sea (9)	Jan-Apr May-July Aug-Sept Oct-Nov	1, 2, 3, 4, 5 1, 2, 5 1, 2, 8, 5 1, 2, 5, 4, 3			
	Labrador Sea	Jan-Apr. May-Dec.	1, 6, 2, 4, 5, 9, 8, 1, 6, 5, 2, 9,			
	Grand Banks & Scotian Shelf	Jan-Apr. May-Dec.	8, 6, 1, 2, 9, 3, 4, 5, 11 8, 6, 1, 9, 10			

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
4. Forecast Ice Concentration/Thickness Chart
5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

Footnotes to Table 4.3

(1) Exploration and production data product requirements will be a function of the type of drilling and production systems employed.

(2) Includes drillships, platforms and semi-submersibles limited to seasonal operations (July-December).

(3) Includes drillships and platforms capable of year round operations.

(4) Artificial islands.

(5) Exploration drilling in this area likely to be seasonal until at least 1995.

(6) Presently seasonal operations. In future could be year round.

(7) Construction activity encompasses the building of artificial islands for exploration or production as well as the installation of other offshore structures such as subsea pipelines, well connections etc. It is assumed construction activity is limited to open water and low ice concentration periods.

(8) Seasonal extension of artificial island construction is possible with ice strengthened dredges.

(9) Assuming year round production is from artificial island platforms.

TABLE 4.4 ACTIVITY/INFORMATION PRODUCT MATRIX (Page 1 of 1)

GROUP & ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS (in order of priority)	TIME NEEDS		FREQUENCY
				NOWCAST	FORECAST	
DND Anti-Submarine Warfare	North Atlantic North Pacific	Year Round	8, 10, 9	2 hrs		As Available
DND Ship Movements Including Fisheries Surveillance	North Atlantic North Pacific	Year Round	8, 9, 10	2 hrs.		" "
	Gulf of St. Lawrence	Dec-Apr	8, 1, 2, 4, 5	2 - 6 hrs.	12 - 48 hrs.	Daily
	Labrador Sea & East Nfld.	Year Round	8, 1, 2, 4, 6	2 - 6 hrs.	12 - 48 hrs.	Daily
	Eastern Arctic	July-Sept.	8, 1, 2, 4, 6	2 - 6 hrs.	12 - 48 hrs.	Daily
DND Search & Rescue Environmental Emergencies	All Canadian Waters	Year Round	8*, 1, 2, 4, 5, 6, 7	2 - 6 hrs.	12 - 48 hrs.	Daily

(1) This information should be available to the METOC Centres within 2 hours of observation time.

* DND highest priority is wave information.

Information Product Legend for Tables 4.1 - 4.4

1. Ice Imagery and Interpretive Charts
2. Ice Analysis Chart
3. Ice Ridge Distribution Chart
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5. Forecast Ice Drift/Pressure Chart
6. Iceberg Location Maps - Nowcast and Forecasts
7. Vessel Location Map
8. Wave Data Charts - Nowcast and Forecasts
9. Sea Surface Temperature Chart
10. Ocean Features Analysis Chart
11. Ice Accretion Chart

5. CONCLUSIONS AND RECOMMENDATIONS

From the deliberations of the Information Standards Committee and the input received from users and others during the course of the study, it is possible to draw the following conclusions:

5.1 Adequacy of Radarsat SAR

A major conclusion from the discussions of the Radarsat Information Standards Committee and the data contained in Table 3.1 and 4.1 - 4.4 is that, depending on location, season and application, Radarsat SAR imagery will meet some tactical as well as most strategic ice reconnaissance requirements, particularly when close tactical support is available. In this context, close tactical support means the provision of vessel-based helicopters and vessel-mounted sensors capable of sensing conditions in the immediate vicinity. The turnaround time requirement of 2 hours for uninterpreted imagery can be met according to MDA. The question of low- vs high-resolution imagery (100 m vs 25 m)* is a matter of the availability of low- vs high-speed digital communication links to the user and the compatibility of such links with the turnaround time that is acceptable in each application.

Radarsat covers the Beaufort Sea, NW passage and Baffin Bay portions of the arctic daily as required. For more southerly latitudes, daily coverage normally would not be achievable; however, the baseline Radarsat SAR configuration calls for a selectable swath mode of operation. Four swath positions are specified at present ranging from a near-side incidence angle of 20° to a far-side incidence angle of 45° - the average swath width is 200 km. The SAR may be switched from one swath mode to another during a pass to ensure adequate coverage of specific areas, but at the expense of less coverage for other areas of lesser importance. The latter limitation might be overcome to some extent by the use of other satellite data including Landsat when there is no

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*According to Reference 1, a resolution of 100 m meets many of the critical strategic requirements, particularly edge location and ice concentration, wanted by the major users such as the Canadian Coast Guard and General shipping, and Oil and Gas shipping.

cloud cover, and the European ERS-1 which likely will be launched prior to Radarsat with a C-band SAR on board.

In addition to coverage deficiencies at lower latitudes, Radarsat does not meet tactical resolution specifications for certain parameters which, as listed in Appendix C of the User Requirement Study (Ref. 1), can be as stringent as 5 m. in some cases. Also, the angle of incidence, even at 45^{o}, is insufficiently large for Radarsat to be totally effective in detecting icebergs. Despite these deficiencies, Radarsat extends significantly the ability of the Canadian ice information system to meet the strategic and tactical needs of operational users.

This conclusion does not suggest that the aircraft program should be abandoned. There are some parameters that probably will best be established from an aircraft such as thickness estimates and ridge data, and iceberg observations. What the conclusion does suggest is that the aircraft can be used more efficiently and can concentrate on those products that cannot be provided reliably from a satellite.

5.2 Radarsat Contribution to Forecasting Capability

The synoptic nature of Radarsat coverage, where all regions of Canadian sovereign waters and territories are covered on a regular basis, makes possible the assembly of a remarkably valuable data base for use in forecasting. Improved forecasts depend on the established validity of models including their numerical parameters, and the availability of adequate data for initializing the models. Radarsat can provide significantly better data for both these requirements thus improving the ability to forecast ice, ocean and meteorological conditions over present capabilities using currently limited sources of data. This benefit could well be the most important contribution that can be made by Radarsat because of the economic value of better forecasts to users, and the safety implications for those operations where human lives are at stake.

5.3 Other Radarsat Sensors

Offshore drilling operators rely heavily on environmental forecasts for the safe and efficient planning and execution of their day-to-day operations. In turn, the forecasters depend on reliable initializing data for their models, a major component of which is wind field and wave data. Currently, data is provided by ships of opportunity, DND sources and from the rigs themselves. The improvement that could be provided by regular and reliable scatterometer data from Radarsat (and other satellites) would be significant according to the consultant and environmental modelling communities. We conclude that a scatterometer should be included on Radarsat because it would improve the ability to forecast waves and winds thus contributing to the safety of offshore structures.

The addition of a radar altimeter on Radarsat might provide better wave data (for truthing the scatterometer-derived wave forecast) and geoidal data. We conclude that an altimeter may enhance the value of Radarsat.

The Scanning Multifrequency Microwave Radiometer (SMMR) is emerging as a very powerful complementary instrument to the SAR. Ideally it should be located on the same satellite as the SAR but it can also be operated from a different satellite. In this case the synergism depends on how well the two data products can be merged, which is no simple feat even with the SMMR located on the same satellite. A SMMR type instrument has the potential of providing a host of meteorological, oceanographic and ice parameters, depending on the number of frequencies and polarizations available.

In the case of ice it has been conclusively shown that SMMR type data can provide ice concentration to an accuracy of about 10%, it can distinguish between the major ice types present such as first year, multiyear and thin ice to an accuracy of 10-15%, and finally can provide the ice edge location to an accuracy of about half a footprint. Using the 37 GHz channel this amounts to about 12 to 15 km.

Forecasters depend on reliable information on a regional, hemispheric or global basis to initialize and update their models. For the first time, this can be achieved by using SMMR data because the information comes in a gridded format on a scale which is compatible with the meteorological and modelling scales in use. The other big advantage is that the data does not come in image format as the SAR. It is quantitative in nature. Should an image be desirable it can be generated with the data. On the other hand the SAR provides an image first, and it is very difficult today, even on the research level to generate numerical values from the SAR in a gridded format for use in models.

A similar situation exists with winds over the ocean; however, ocean results have been overshadowed by results from the scatterometer on SEASAT-A. Based on SEASAT results, the SMMR can provide wind speed information between 0-25 m/s with an accuracy of 2 m/s. On the other hand, the scatterometer provides wind speed information between 4-26 m/s with an accuracy of 1.3 m/s. In addition the scatterometer could provide wind direction to an accuracy of plus or minus 16^{o} for the wind speed range quoted above. Attributes of the SMMR in comparison with other sensors are listed below.

TABLE 5.1

SEASAT SENSOR PERFORMANCE

Sensor	Observable	Demonstrated Accuracy	Demonstrated Range of Observable
Altimeter	Significant Wave Height ($H_{1/3}$)	$\pm 10\%$ or 0.5 m	0 to 8 M
	Range Precision	7 CM	$H_{1/3} \leq 5$ M
Scatterometer	Wind Speed	1.3 M/S	4 to 26 M/S
	Wind Direction	$\pm 16^\circ$	4 to 26 M/S
Scanning Multichannel Microwave Radiometer	Sea Surface Temperature	1.0°C	10° to 30°C
	Wind Speed	2 M/S	0 to 25 M/S
	Atmospheric Water	$\pm 10\%$ or 0.2 GM/CM^2	0 to 6 GM/CM^2
Synthetic Aperture Radar	Wave Length	$\pm 12\%$	Wave Length $\gtrsim 100$ M
	Wave Direction	$\pm 15^\circ$	Wave Length $\gtrsim 100$ M

In addition to model initialization and small-scale ice reconnaissance, the SMMR can be used for sea surface temperature mapping when an appropriate channel is added. We conclude that a SMMR will enhance the value of Radarsat for both ice and ocean information.

5.4 Information Products

Eleven information products have been identified and assessed by users as to their priorities based on geographical location and season. Ice imagery was listed as the top priority product by oil and gas shipping, offshore drilling and by DND in waters where ice is encountered. Interestingly the Coast Guard listed the Ice Analysis Chart as first priority, a product that was second for the other users. However, the Ice Analyis Chart should become increasinglyly dependent on satellite SAR imagery when it becomes available. We conclude that Ice Imagery is the highest priority information product, followed by the Ice Analysis Chart and then the ice forecast products.

Wave Forecast Data Charts are the highest priority oceans information products according to Tables 4.1 - 4.4. We conclude that the value of better wave information products justifies a more thorough assessment of how a satellite scatterometer or SMMR can be integrated into the existing oceans information system.

5.5 Communications System

In the earlier meetings of the Information Standards Committee, considerable time was spent on the ice and oceans information system architecture. The appropriate form is highly dependent on the operational philosophy of the companies involved. For example, the industrial groups involved in oil and gas shipping expressed a desire to monitor operations from headquarters in Calgary and possibly to participate in strategic decisions in the route planning of their vessels. We concluded that provision should be made for such head offices to be Intermediate Processors (IPs) in the system.

Since most routing decisions will be made on board the ship, a careful study is needed as to the type of data and manipulative abilities the operator needs on board the vessel to perform the routing mission effectively. If zoom, roam and enhancement capability is required for the SAR imagery, then appropriate storage and communications facilities need to be planned. It could be that these functions can be performed equally effectively elsewhere (IIC or a shore-based company facility), thus reducing complexity on-board the vessel. We conclude that a communications systems study needs to be performed involving both the industry and the government to arrive at a system structure that satisfies the needs of users.

5.6 Interpretation of Radarsat Data

The information products described and dealt with in this report are those needed by a limited community of users to derive the parameters required for their operations. However, particularly in the case of satellite SAR and radiometric sensors which involve young technologies, ice and oceanographic scientists are still in the early phases of learning how to analyse and interpret the data. For example, even a casual glance at a SAR image of the ocean suggests there still is a wealth of information yet to be uncovered through a more complete understanding of the interaction between electromagnetic waves, the ocean surface and its underlying features. We conclude that more research is needed on the interpretation of SAR and radiometric imagery, and the physical phenomena displayed by such imagery.

5.7 Archiving

During the course of the study, the question of archiving derived products arose from time-to-time from users that are not operational in the sense of the captain of a vessel, but nevertheless had need for derived information products that would be stored in some form of data base. In general, such users are found in government departments, although several environmental consultant firms maintain their own large data bases.

Archival information is important to operational users because of its value in ice and atmospheric model construction, and in the setting of regulatory parameters (e.g. load-line limits). Archivists generally complain that their needs are often left to the last or neglected entirely during the planning phases of most information systems. We conclude that archival needs should be considered alongside operational requirements of the ice and ocean information system.

5.8 The On-Going Design Process

As stated at the beginning, the present work is taking place at a time eight years before the planned launch of Radarsat, and at least five years before year-round vessel operations in the arctic. Needs will undoubtedly change before design decisions are necessary.

However, it is worth being reminded that there is an ice and oceans information system operating to-day (as depicted in Figure 2.1) serving operators in the arctic summer (drill rigs and shipping). The extension of the season and the introduction of new sources of data into the system will represent evolutionary changes to the on-going ice and ocean information services. We conclude that an on-going system design process is required that avoids the need for revolutionary change, and that introduces new data sources such as Radarsat gracefully into the existing ice and oceans information system.

5.9 Recommendations

On the basis of the above conclusions, it is recommended that:

1. An investigation be made as to how satellite scatterometer and SMMR data can be integrated into the present ice and oceans information system.

2. A detailed study be made of the future communications requirements of the ice and information systems involving both the industry and the government, with particular emphasis on the introduction of satellite data products and the use of Canadian facilities such as Anik and M-Sat.

3. A continuing user liaison function be performed which keeps the Radarsat Project Office in contact with the user community and the major components of the ice and oceans information system. The purpose of such liaison is to ensure that the design process is evolutionary and cohesive in character, and that adequate continuing communications exists among the key performers.

4. Research be supported on the interpretation and analysis of satellite SAR and SMMR imagery for ice and oceanographic applications.

5. A study be conducted on the needs of the archiving community for satellite and aircraft derived ice and oceans information, and that the system provide for such needs.

REFERENCES

1. "Preliminary Statement of User Requirements for Ice and Ocean Information", Philip A. Lapp, David J. Lapp, Radarsat Project Report 81-3.

2. "Radarsat Benefit Analysis Study", C. F. Pound, Radarsat Project Report 82-5.

3. "AES Communications Study", Spar Aerospace Ltd., MacDonald, Dettwiler Assoc. and Philip A. Lapp Ltd., March, 1981.

4. "Platform, Sensor and Communication Tradeoff Study" J. N. Barry, Radarsat Project Report 82-4.

5. "Radarsat Ground Stations Performance Requirements and Design Concepts", MacDonald, Dettwiler Assoc., Report 00-2453-ROO, March, 1982.

APPENDIX 1

RADARSAT INFORMATION STANDARDS COMMITTEE

MEETING ATTENDEES

Name	Affiliation and Address	No. of Meetings Attended
Philip A. Lapp Chairman	Philip A. Lapp Limited Suite 302 14A Hazelton Avenue Toronto, Ontario M5R 2E2	5
David J. Lapp Secretary	Polar Research & Engineering Suite 303, 14A Hazelton Avenue Toronto M5R 2E2	5
C. F. Pound	Philip A. Lapp Limited Suite 904 280 Albert Street Ottawa, Ontario K1P 5GB	2
J. N. Barry	Philip A. Lapp Limited Suite 904 280 Albert Street Ottawa, Ontario	1
E. Shaw	Radarsat Project Office 110 O'Connor Street Suite 200 Ottawa, Ontario	3
R. O. Ramseier	AES Room 301 Journal Tower South 365 Laurier Avenue West OTTAWA, Ontario K1A OH3	1
Alex Beaton	AES Room 301 Journal Tower South 365 Laurier Avenue West OTTAWA, Ontario K1A OH3	1

Name	Affiliation and Address	No. of Meetings Attended
T. F. Mullane	Room 301 Journal Tower South 365 Laurier Avenue West OTTAWA, Ontario K1A OH3	4
S. Peteherych	Atmospheric Environment Service 4905 Dufferin Street Downsview, Ontario	1
Clive Jarvis	Atmospheric Environment Service 4905 Dufferin Street Downsview, Ontario	2
R. Robinson	Canadian Meteorological Centre 2121 North Service Road Trans Canada Hwy. Dorval, Quebec	1
Laurence Gray	Canada Centre for Remote Sensing 2464 Sheffield Road Ottawa, Ontario	1
J. R. G. Cox	Spar Aerospace Limited 21025 TransCanada Highway St. Anne de Bellvue, Quebec H9X 3R2	3
Stu Waterman	MacDonald, Dettwiler & Associates 3751 Shell Road Richmond, British Columbia	3
R. Orth	MacDonald, Dettwiler & Associates 3751 Shell Road Richmond, British Columbia	1
Douglas W. Seymour	MacDonald, Dettwiler & Associates 3741 Shell Road Richmond, British Columbia	1
L. Gutteridge	MacDonald, Dettwiler & Associates 3741 Shell Road Richmond, British Columbia	5
Lou Morena	MacDonald, Dettwiler & Assoc. 3751 Shell Road Richmond, British Columbia	1

Name	Affiliation and Address	No. of Meetings Attended
John Halbertsma	MacDonald, Dettwiler & Assoc. 3751 Shell Road Richmond, British Columbia	1
Peter Brunt	General Technology Systems Ltd. 20 Market Place Brentford, Middlesex England	2
B. D. Brodie	Canadian Forces Weather Service Marcom Environmental Services FMO Halifax, Nova Scotia	3
J. A. Gallant	Fleet Systems Canadian Coast Guard Room 844, Tower A Place de Ville Ottawa, Ontario K1A OH3	3
B. Tepper	T & E Coast Guard CGTC-T Tower A, Place de Ville Ottawa, Ontario K1A ON7	2
J. Bryan Mercer	Dome Petroleum P.O. Box 200 Calgary, Alberta T2P 2H8	4
Bharat Dixit	Arctic Pilot Project 5th Floor West 401 - 9th Avenue S.W. Calgary, Alberta T2P 2H8	4
Klaus A. Mueller	Arctic Pilot Project 5th Floor West 401 - 9th Avenue S.W. Calgary, Alberta T2P 2H8	2
Jacques Benoit	Mobil Oil Canada 330-5th Avenue S.W. Calgary, Alberta	2

Name	Affiliation and Address	No. of Meetings Attended
Dave Pearson	Petro-Canada 840 - 7th Avenue S.W. Calgary, Alberta	3
F. J. Eley	Gulf Canada Resources Inc. 401-9th Avenue S.W. P.O. Box 130 Calgary, Alberta T2P 2H7	1
Simon Melrose	McElhanney Surveying & Engineering 999 - 8th Street S.W. Calgary, Alberta	1

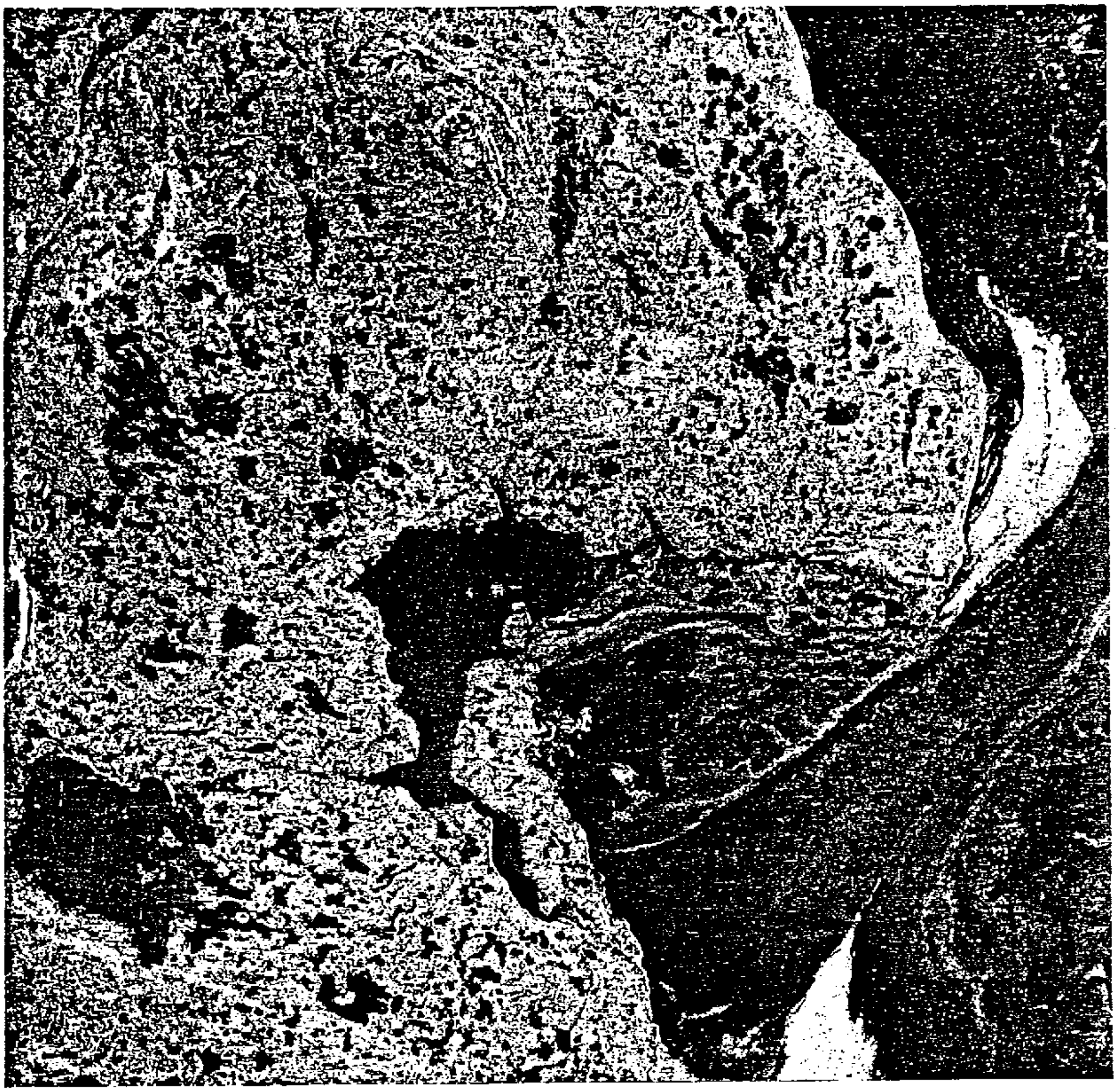
APPENDIX 2

EXAMPLES OF INFORMATION PRODUCTS

Certain of the information products listed in this report are already being produced. Others have only been proposed. The following example products are included in this Appendix.

Product No.	Title
1.	Ice Imagery (uninterpreted)
2.	Ice Analysis Chart
3.	Ice Ridge Distribution Chart
4.	Forecast Ice Concentration/Thickness Chart
5.	Forecast Ice Drift/Pressure Chart
6.	Iceberg Distribution Chart
8.	Wave Data Charts - Nowcast and Forecasts
9.	Sea Surface Temperature Chart
10.	Ocean Features Analysis Chart

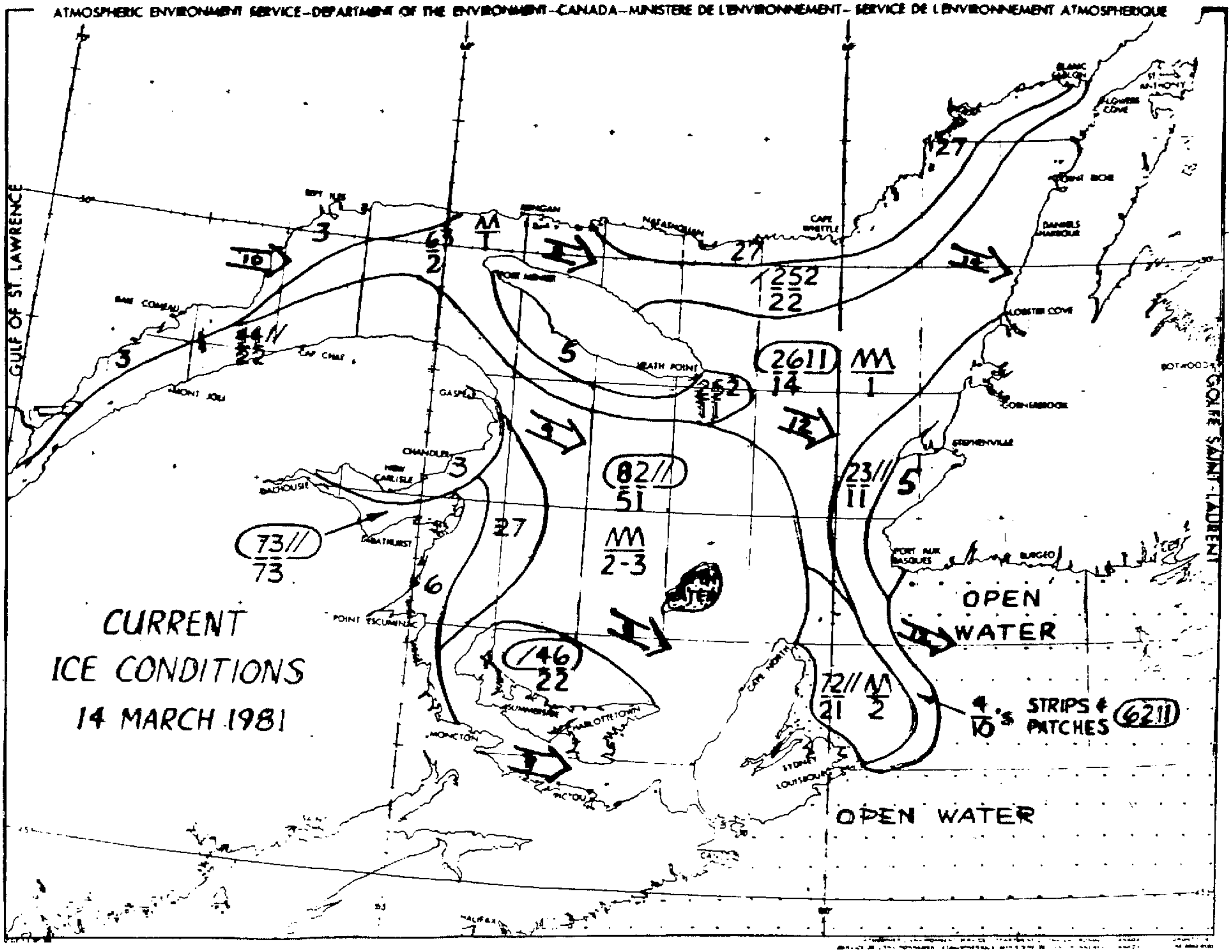
Not available were examples of a vessel location map (Product 7) and an ice accretion chart (Product 11).



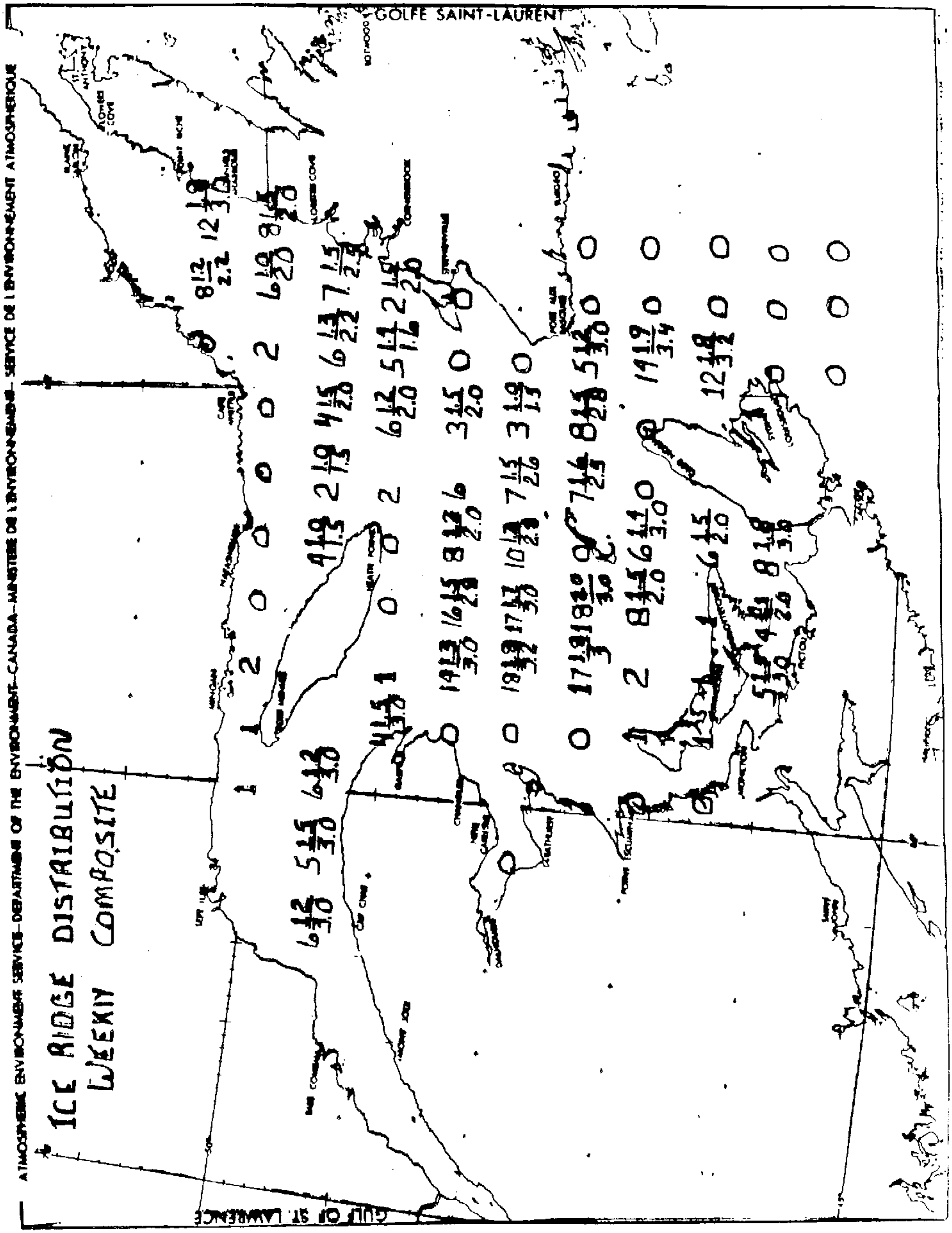
DIGITALLY PROCESSED SEASAT SAR IMAGE, CAMBRIDGE BAY, N.W.T.
ORBIT 1439, OCTOBER 5, 1978, 25 METER RESOLUTION, 4 LOOKS.

All water bodies in this image are ice-covered including the lakes which are covered with fresh-water ice. Most of the visible rafting is generally parallel to the satellite track. The ice on the lakes and on the inner bay is nilas, a thin elastic cover of ice with a thickness of up to 10 centimeters. The surface is smooth because the ice formed in a sheltered area, hence most of the backscatter is derived from the rafted ice. All of the ice in the open water body can be classified as new ice and nilas. The strongly reflecting line which extends from the lower right to the center at the right hand side of the image represents a shear line. The ice to the right of this line consists of consolidated slush and shuga occasionally intermixed with nilas.

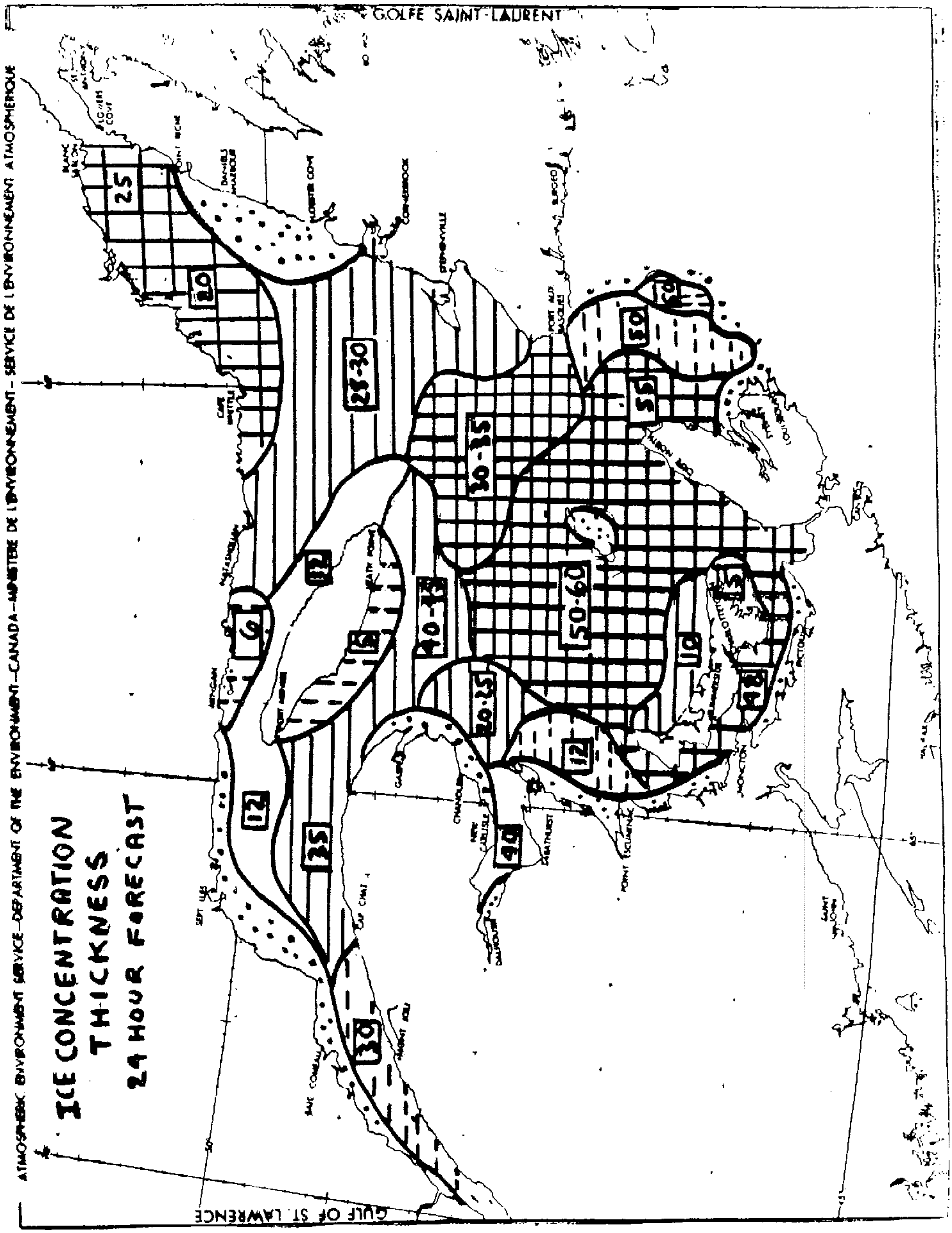
<u>PRODUCT 1</u>   <u>ICE IMAGERY</u> (uninterpreted)



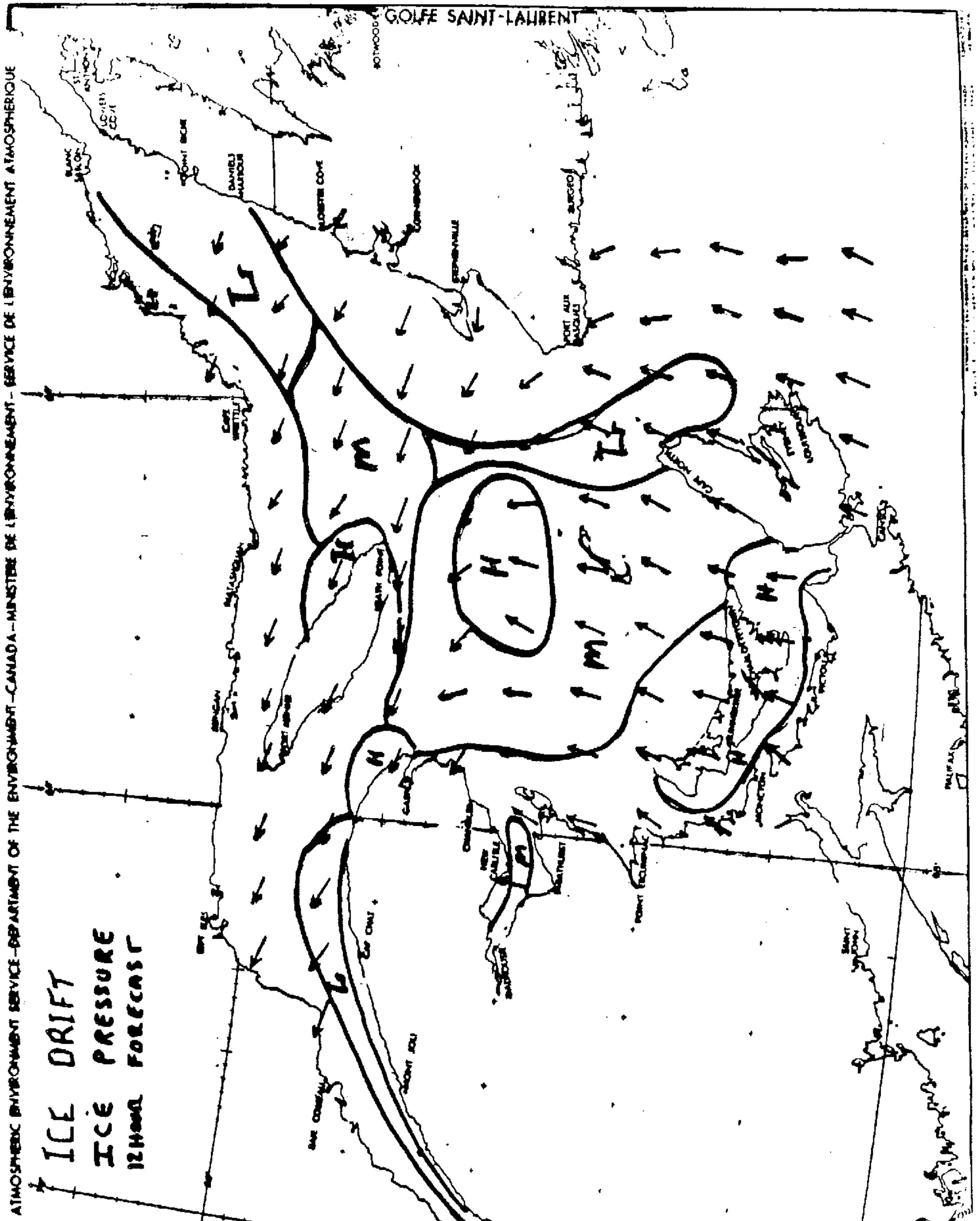
PRODUCT 2 ICE ANALYSIS CHART



PRODUCT 3 ICE RIDGE DISTRIBUTION CHART

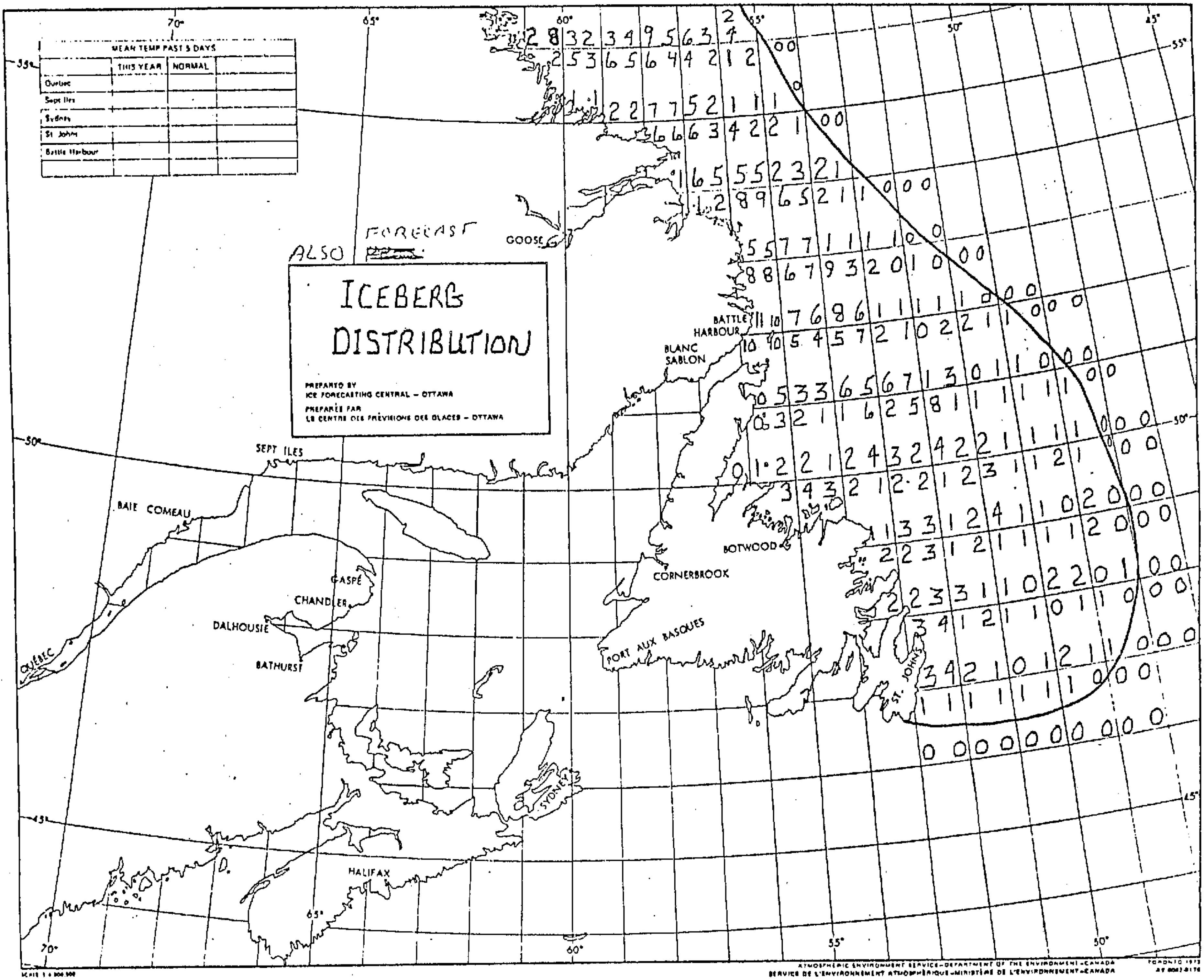


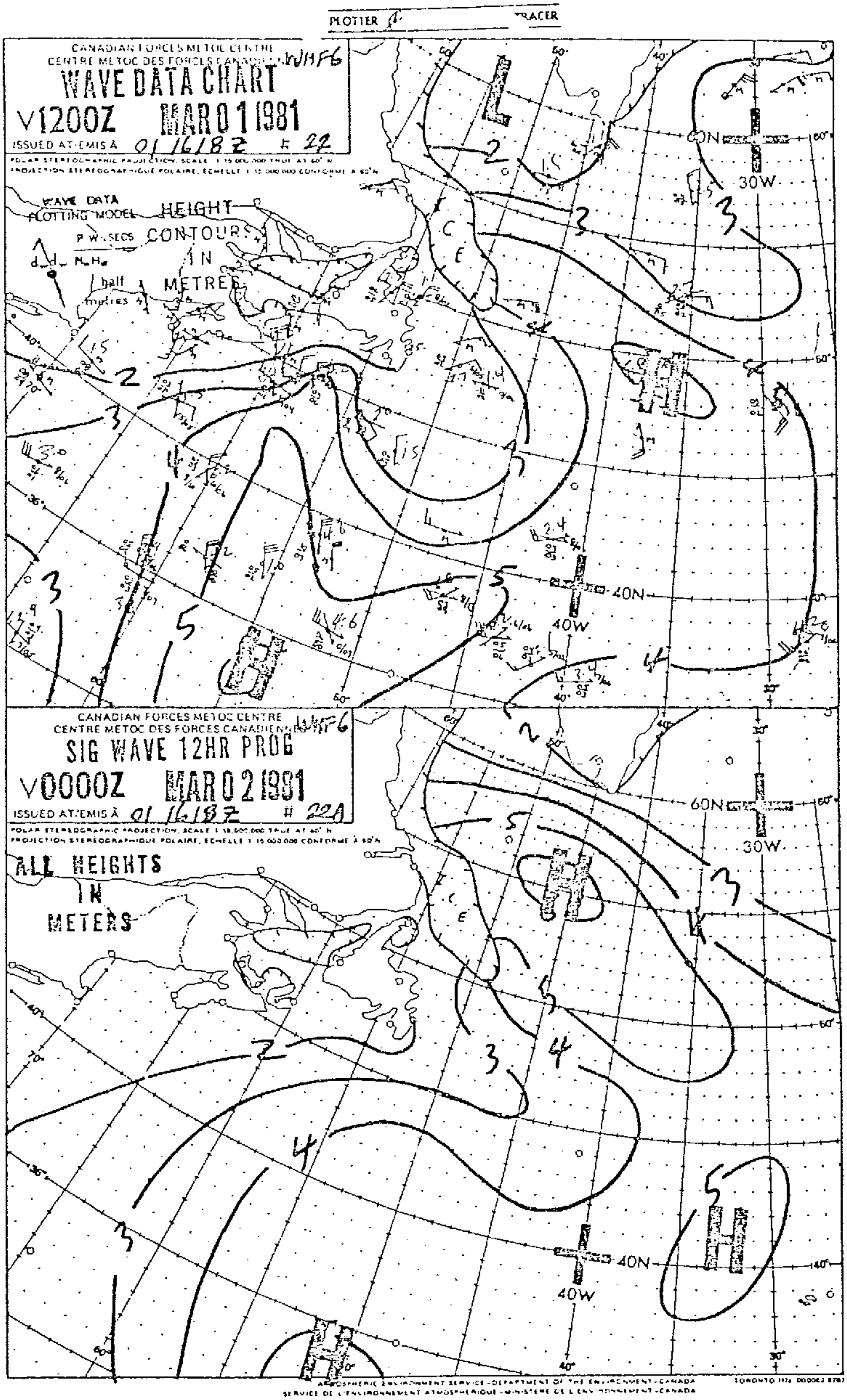
PRODUCT 4 FORECAST ICE CONCENTRATION/THICKNESS CHART



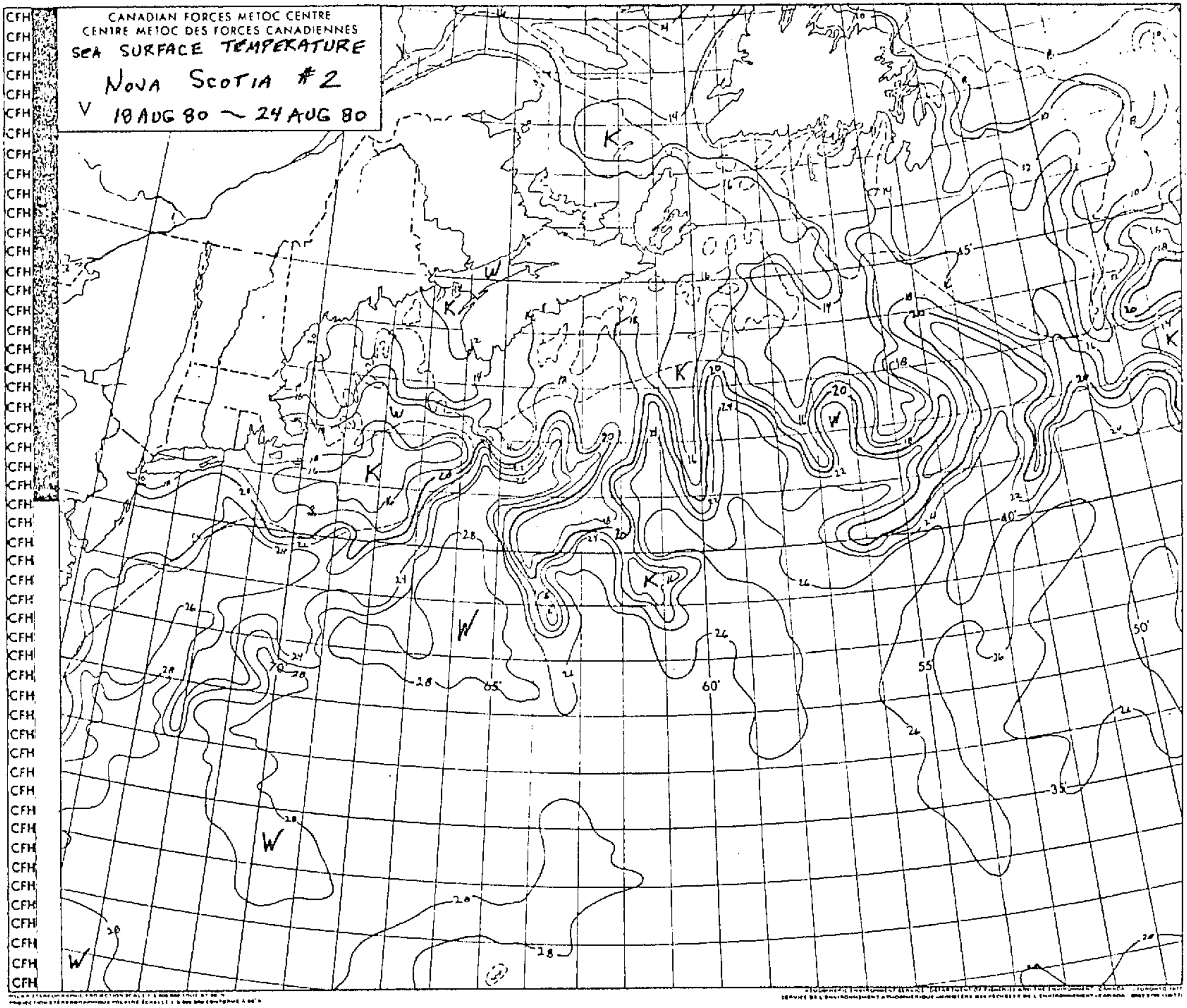
PRODUCT 6 FORECAST ICE DRIFT/PRESSURE CHART

PRODUCT 6 ICE DISTRIBUTION CHART

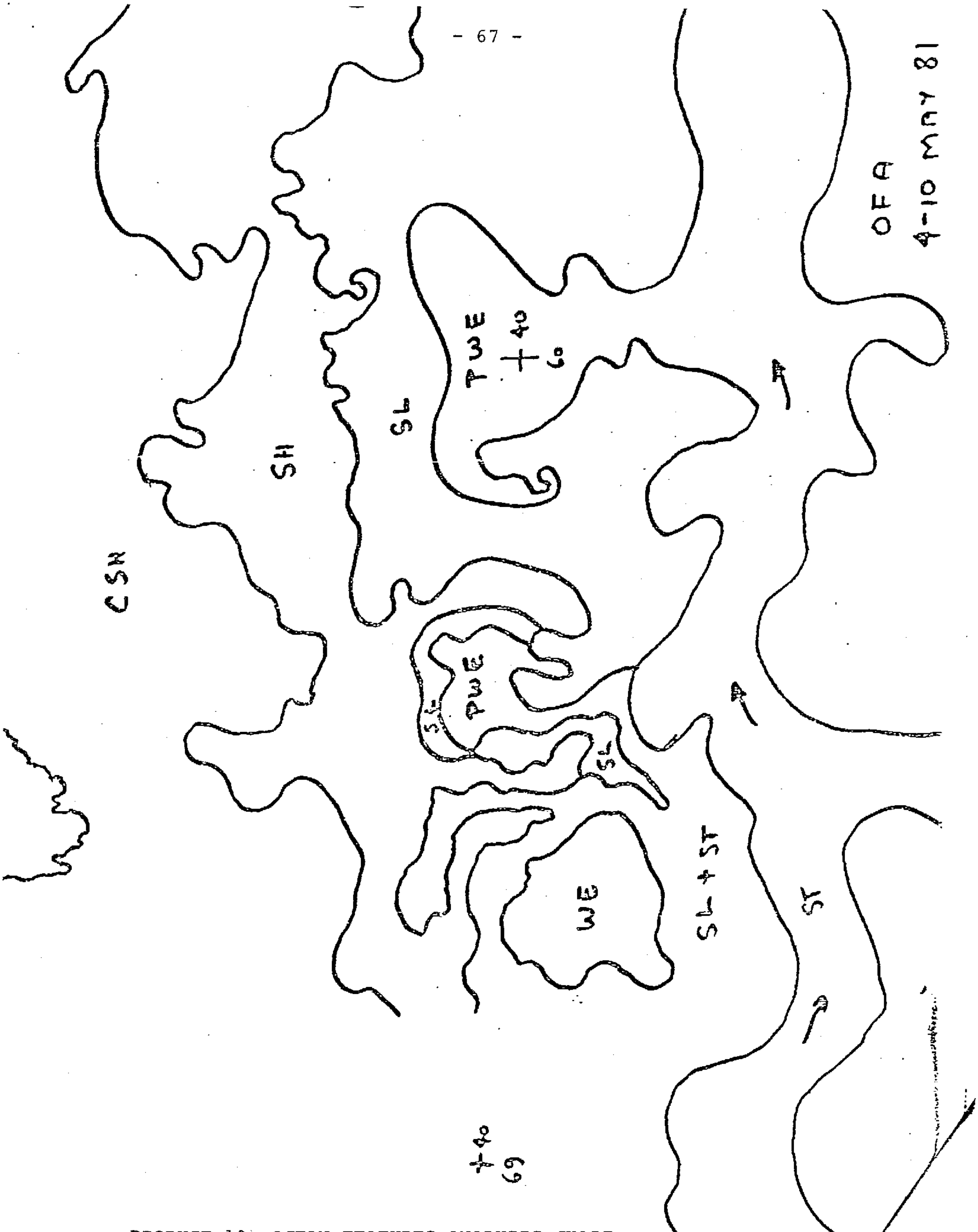




PRODUCT 8 WAVE DATA CHARTS - NOWCAST AND FORECASTS



PRODUCT 9 SEA SURFACE TEMPERATURE CHART



PRODUCT 10 OCEAN FEATURES ANALYSIS CHART